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COMMENTARY

# The Invisible Army

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**ABSTRACT** The "invisible army" of clinical microbiologists is facing major changes and challenges. The rate of change in both the science and technology is accelerating with no end in sight, putting pressure on our army to learn and adapt as never before. Health care funding in the United States is undergoing dramatic change which will require a new set of assumptions about how clinical microbiology is practiced here. A major challenge facing the discipline is the replacement of a generation of clinical microbiologists. In my opinion, it is incumbent on us in the invisible army to continue to work with the American Society for Microbiology (ASM) in meeting the future challenges faced by our discipline. In this commentary, I will first discuss some recent history of clinical microbiology within ASM and then some current challenges we face.

**KEYWORDS** MALDI-TOF, NAAT, emerging pathogens, next-generation sequencing, total laboratory automation

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For almost 40 years, I have been a member of an invisible army of clinical microbiologists. Our enemy is infectious diseases. Our mission has been to discern who the enemies are and raise the alarm when they are a threat. We are usually nameless and faceless to the general public. The job we do to protect them is little understood and even less appreciated. We are people who come from many nations, religions, economic circumstances, sexual orientations, and educational attainment, but we work for a single goal, to defeat disease where we find it so as to relieve and prevent as much human suffering as possible.

In the United States, clinical microbiologists have a common bond forged by our membership in the American Society for Microbiology (ASM). We demonstrate and benefit from this bond by attending ASM-sponsored workshops, meetings, conferences, and audioconferences, by reading, writing for, and editing its journals and its many clinical microbiology and immunology reference books, by participating in ASM-sponsored professional listservs, and by training and mentoring the next generation of its leaders especially through its Committee on Postdoctoral Education Programs (CPEP)-accredited postdoctoral training leading to certification by the American Board of Medical Microbiology (ABMM) and until recently, the American Board of Medical Laboratory Immunology (ABMLI). With the help of ASM, we are constantly learning, training, and teaching because the organisms we combat are ever emerging and changing.

During the past decade, there have been accelerating changes in clinical microbiology. These changes are being driven by an aging population in the industrialized world, impacting how health care is delivered and reimbursed, by the disruptive technologies of nucleic acid amplification tests (NAATs), next-generation sequencing (NGS), matrix-assisted laser desorption ionization–time of flight (MALDI-TOF) mass spectroscopy (MS), and total microbiology laboratory automation (TLA), by the never-ending emergence of new pathogens driven by globalization, urbanization, climate changes, antimicrobial misuse, and our increased capability to detect them, by the unintended consequences of new medical treatments and devices, and by the ability to wirelessly communicate globally at the speed of light. These changes are putting

tremendous pressure on our army. This pressure is likely only to increase as a wave of retirements at all levels within our discipline drains it of significant intellectual capital which will be difficult to replace in the short term.

Volunteers and staff within ASM have been grappling with these challenges over the past decade. Two events are currently shaping the Society's approach to supporting our discipline. One was the formation in 2010 of the Clinical Microbiology Task Force led by David Hooper at the behest of then ASM President Roberto Kolter. This task force accomplished two things. First, it created a new approach to programming clinical microbiology content within the General Meeting (1) which continues in the Clinical and Public Health Microbiology track at the Microbe meeting. The second was to establish the Professional Practice Committee (PPC). The purpose of the PPC is to oversee activities related to the professional development and practice of clinical microbiology. The committee oversees the American College of Microbiology which is responsible for ASM's three certification boards, ABMM, ABMLI, and National Registry of Certified Microbiologists, as well as the Medical and Public Health Microbiology and Medical Laboratory Immunology postdoctoral training programs, the Evidence-based Practice Guidelines Committee, the Clinical Microbiology Mentoring Committee for professional development of doctoral and non-doctoral-level clinical microbiologists, the Clinical Microbiology Portal to provide resources of value to bench and supervisory clinical microbiologists electronically, and the Professional Development Committee to provide low-cost, high-quality clinical microbiology continuing education courses electronically in collaboration with industry partners. The PPC in conjunction with the Clinical Laboratory Practice Committee and Professional Affairs Committee of ASM's Public and Scientific Affairs Board also works to improve rules and regulations that govern the manner in which clinical microbiology is practiced (2).

The second important event, Camp Clin Micro, occurred in 2011 (3). Camp Clin Micro was organized independently of ASM and brought together thought leaders from the clinical laboratory, FDA, and industry to take a 5-year future look to determine the direction that the discipline was progressing (4–6). They also asked if ASM was meeting the needs of the discipline (7).

Key points anticipated at this meeting have come to pass. To paraphrase, some predictions from the Camp Clin Micro meeting follow.

1. The clinical microbiologist will need to become a key member of multidisciplinary teams such as antimicrobial stewardship (5).
2. Microbiology laboratories will no longer be judged solely by their ability to generate revenue. Evidence-based practice guidelines and outcome studies will determine the clinical effectiveness of the laboratory (5).
3. The jobs of the clinical microbiologists will change dramatically due to laboratory consolidation and automation of specimen processing, organism identification, and susceptibility testing (5–7).
4. The clinical microbiology community will need to work with other clinical scientists with common interests and goals to set the agenda for how infectious disease testing should be done (5).
5. Meetings like the Clinical Virology Symposium (now an ASM-sponsored meeting) and regional clinical microbiology meetings are more attractive than the larger Microbe meeting because they are more geared to the educational and professional development needs of their attendees (7).

With hindsight we can say with some confidence that the visionaries at Camp Clin Micro did an exemplary job of looking into the future. What can we say about the future in 2017? I will attempt to answer two essential questions about how clinical microbiology will be practiced in the next decade.

1. How will technology affect the practice of clinical microbiology?
2. How do we attract the next generation of clinical microbiologists?

## HOW WILL TECHNOLOGY AFFECT THE PRACTICE OF CLINICAL MICROBIOLOGY?

Technologies like NAAT and MALDI-TOF MS have been widely adopted in the past decade, and others, including TLA and next-generation sequencing, which have begun to make inroads, will most likely be more widely adopted in the coming years. These technologies will greatly impact clinical microbiology practice in at least four ways.

1. The introduction of Clinical Laboratory Improvement Amendments (CLIA)-waived NAATs for group A *Streptococcus*, influenza virus, and respiratory syncytial virus has greatly improved the accuracy of point-of-care testing for these agents, potentially improving the quality of care in urgent care clinics and similar care settings. Testing and treating in these settings are likely to relieve pressure on both emergency department (ED) and clinical microbiology laboratories during periods of high utilization of both resources. At the same time, clinical microbiologists will need to play a significant role in choosing tests to be used and to assure that training and performance of tests in these setting meet the highest quality care standards.
2. NAATs have replaced the more-traditional methods of culture, serology, and antigen tests in the clinical virology laboratory, providing answers that are fast and much more accurate than ever before (8). Syndrome-specific NAATs have proven to be reliable and reduced the time to detection for agents of diarrheal and respiratory pathogens (9). This has resulted in their widespread adoption. The usefulness of syndromic detection of central nervous system pathogens is currently less certain with issues of sensitivity and specificity not yet resolved (10).
3. Next-generation sequencing may be the wave of the future in molecular diagnostics and has a range of applications, including analysis of the human microbiome, transcriptome, and resistome, detection of genetic sequences directly from clinical samples (metagenomics), pathogen discovery, and public health surveillance.
4. TLA promises to greater increase the efficiency of specimen processing for the vast majority of clinical microbiology specimens, freeing clinical scientists to perform more-complex tasks (11).

A significant capital investment is required for laboratories that adopt these technologies. There is not a single platform that can be used for all the different nucleic acid tests, so laboratories typically have multiple platforms each costing five to six figures. MALDI-TOF MS requires a six-figure initial investment and a five-figure annual service contract (12). TLA requires an even greater investment in the millions of dollars. The days of a microbiology laboratory with just a biologic safety cabinet, microscope, incubator and a few identification kits and tubes are over.

Although we tout the wonders of these technologies, do they actually improve care of patients? And if they do, how do we assure they are used efficiently? In a May 2014 editorial in the *Journal of Clinical Microbiology*, Gary Doern made a plea for the clinical microbiology community to shift some of its research focus from detection and identification of microbes to studies that described how these advances in detection and identification of microbes actually improve patient outcomes (13). He reasoned that the impact of these technologies on patient outcomes could be used to justify the economic investment necessary for these new expensive technologies (13). Using the search term "clinical outcomes" and allowing 6 months for the discipline to address this plea, a search of the *Journal of Clinical Microbiology* between November 2014 and March 2017 revealed 43 articles whose abstract or title contained that term. Review of the abstracts revealed that only 11 of those 43 articles contained data that examined the impact of technologies on such metrics as length of hospitalization, time to appropriate antimicrobials, mortality, or cost savings. Clearly, the discipline needs to do more to demonstrate the clinical impact of these new technologies.

Why is it important? Clinical practice guidelines provide a framework to translate

medical evidence into everyday clinical care (14). These practice guidelines frequently make recommendations that directly impact the laboratory. For example, in 2016, the U.S. Cystic Fibrosis Foundation and European Cystic Fibrosis Society wrote guidelines on the management of cystic fibrosis patients infected with nontuberculous mycobacterium. Of the 50 consensus guideline recommendations, 23 were directly related to clinical microbiology laboratory practices (15). Both the Clinical Microbiology Task Force and Camp Clin Micro made strong recommendations that ASM begin to generate guidelines that specifically address the impact of laboratory practices on patient outcomes. In 2011, a committee led by Alice Weissfeld was formed within the PPC to develop evidence-based clinical microbiology guidelines. Working in collaboration with the Laboratory Medicine Best Practice Initiative of the Centers for Disease Control and Prevention (CDC), this group has contributed many thousands of hours, and ASM has provided significant financial support to generate guidelines that address how laboratory practices impact patient outcome. In January 2016, this group published a systematic review of the effectiveness of practices aimed at reducing the time to targeted therapy for patients with bloodstream infections. An important conclusion of this study was that of 1,827 papers identified through electronic database searches, only 16 studies were suitable for analysis, and fewer still were considered of good quality (16). Clearly, our discipline needs to contribute studies to the literature that address one of the major concerns, improving sepsis outcomes.

Information technology beyond the electronic record is also impacting clinical microbiology practices. Information flows (17) are accelerating at higher and higher rates, allowing clinical microbiologists to acquire knowledge and solve problems at rates that were in the realm of science fiction a generation ago. An example of these information flows are the two professional listservs maintained by the ASM, ClinMicroNet and the Division C listserv. These listservs, both begun by Mike Miller in 1995, allow instantaneous communication among approximately 2,000 ASM members located throughout the world. We use them daily to ask questions about best laboratory practices, for help solving difficult patient care questions or identifying unusual organisms, to learn about emerging disease threats, or query our colleagues about problems with diagnostic reagents, tests, or instruments. They have the added benefit of forging a global microbiology community that has been mobilized to address the H1N1 2009 flu pandemic, the Ebola virus epidemic, and the current Zika virus pandemic. A second example is ProMED-mail which is a moderated listserv that tracks global disease outbreaks and epidemics in real time. It is essential reading in the era of global disease threats such as Ebola, avian influenza A H7N9, Middle East respiratory syndrome-coronavirus (MERS-CoV), dengue, Chikungunya, and Zika viruses. No longer does the clinical microbiology community need to wait for the CDC's *Morbidity and Mortality Weekly Report* or *Bulletin of the World Health Organization* to learn of outbreaks and epidemics, although both continue to be important resources.

## HOW DO WE ATTRACT THE NEXT GENERATION OF CLINICAL MICROBIOLOGISTS?

Workforce surveys report that the clinical microbiology army is graying. In a 2016 laboratory workforce survey published in *Medical Laboratory Observer* (MLO) (18), close to half the respondents (42%) were between 56 to 65 years old, and another quarter (28%) were between 46 to 55 years old. These data are admittedly flawed, since 80% of respondents were either laboratory supervisors/managers or directors and thus will tend to be the more experienced members of the laboratory. It also does not directly address clinical microbiology staffing. However, I ask the reader, look around your laboratories, do these numbers seem reasonable to you?

One of the questions that ASM has struggled with is what can it do to attract young people to our army? Although TLA, syndromic NAAT testing, and automated serologic testing may reduce the need for bench technologists to some degree, a shortage currently exists. With the wave of retirements anticipated by all clinical laboratory disciplines, those shortages are likely to worsen, at least for the short-term, and perhaps

longer (18). Additionally, where will the volunteer leaders come from to fill the many important roles within the ASM both at the national and branch levels?

Although ASM has several social media venues such as Facebook pages, Twitter feeds, webcasts, and blog posts, I believe that we in the profession have to recruit young people face-to-face to convince them that this is a great career path. One of the actions that ASM is doing to facilitate recruitment to careers in microbiology is to provide speakers from a variety of microbiology disciplines to ASM student chapters so they can be aware of career opportunities. However, there are relatively few student branches, and there is a significant need for young microbiologists to join our ranks.

Over the 32 years of advising premed undergraduates and recent graduates, I have been fortunate to meet several young people who loved science and wanted to help people but for whom medical, graduate, or nursing school was not an option. For some of them, working as a clinical microbiologist becomes a career aspiration. Despite having a college degree, frequently with a major in microbiology, they quickly learn that jobs working in clinical microbiology are closed to them because they lack necessary credentials. Often burdened by significant student debt, attending a medical/clinical laboratory science program is out of reach. UCLA has developed a highly innovative 1-year Clinical Microbiologist Scientist program open to college graduates with a degree in microbiology which qualifies the individual for both American Society for Clinical Pathology (ASCP) certification or California licensure as a clinical microbiologist. The individuals have a set curriculum, which is 40 h/week, and are paid an hourly wage with a job title of Clinical Laboratory Technologist Apprentice. ASM has a task force working with the National Accrediting Agency for Clinical Laboratory Science to develop a curriculum that could be used nationally for such programs. This program will be geared for clinical microbiology laboratories who are facing recalcitrant staff shortages to provide structured "on the job training" for individuals with appropriate educational backgrounds.

For individuals with doctoral degrees, ASM has long supported postdoctoral training both in medical and public health microbiology and in medical laboratory immunology. The microbiology programs lead to certification via written examination by the ABMM. This certification qualifies an individual as a director in the 12 U.S. states that require licensure, and it is a credential that is widely sought by employers recruiting for leadership positions in hospitals, health care systems, commercial and state, county, and city public health laboratories, governmental agencies, including the CDC, FDA, military, and the pharmaceutical and diagnostic industries. Strong leadership in all these entities is essential for success in battling our invisible enemies. ASM certifies 20 training programs open to scientists with a doctoral degree. The numbers of these programs have increased by two thirds in the past decade due to the recognized need for individuals with these skills and a strong job market based in part on a wave of retirements in this sector. Eleven additional programs accredited by the Accreditation Council for Graduate Medical Education (ACGME) are restricted to pathologists only.

As a director of an ASM-approved fellowship program, I have noticed a highly encouraging trend in the numbers and quality of the applicants. For our single position in 2016, we had 135 applicants of whom we judged 20 to be highly qualified. We anticipate having a similar number of applicants for our 2018 open position. Part of this is clearly driven by disillusionment among a subset of graduate students and postdoctoral fellows who see their mentors chase after research funding. On a more positive note, the NIH's focus on translational research means early career scientists are frequently generating data that will inform diagnostic approaches. They become interested in the practical application of their work and decide to pursue it as a career. For me, these individuals are strong candidates for training. Another exciting trend is that two to four of the applicants each cycle are medical laboratory scientists who pursued doctoral degrees because they wanted to have a leadership role in clinical microbiology

while developing an in-depth knowledge of the ceaseless parade of novel pathogens that we are battling. They too are strong candidates.

## WHAT WILL THE FUTURE BRING FOR OUR INVISIBLE ARMY?

ASM is now a global society with one-half of its 50,000 members coming from outside the United States. The Society is facing financial challenges because once stable revenue streams such as meetings, books, and journals are being challenged by changes in technology which make information more readily available in real time and generally for free. The open-access movement (19), in particular, has changed journal publishing models, impacting one of the most stable of the ASM's revenue streams. UpToDate has changed the manner in which we use reference books, if we use them at all, as has PubMed, Google searches, and Wikipedia.

As has been discussed in this article, ASM remains essential for the success of our army. How can we best respond to support the Society which I have argued is essential for our success but whose resources are becoming more limited?

ASM more than ever really needs our ideas and actions. The clinical microbiology army is highly regarded by ASM staff and leadership as being fully committed to and tireless volunteers for the Society. We need to work closely with ASM to create the solutions that will take us through the next decade and beyond.

You have much to offer, and there are many ways you can contribute to the success of the Society to support our army.

1. Speak to junior high, high school, and college students about a career in clinical microbiology. For those who show interest, agree to mentor them. It takes little time and yields big rewards for the mentee and mentor.
2. Become involved by reviewing papers for the evidence-based practice guidelines, and provide unpublished data for that effort.
3. Actively participate in the listservs that are available—ask and answer questions as they arise and participate in surveys so we have a better idea of how we address problems as a profession.
4. Find out how to volunteer for the many activities that the Society sponsors that support our army. The volunteer of today is the leader of tomorrow.
5. Volunteer through your local ASM branch to be a representative to the new governing body of ASM, the Council of Microbial Sciences.
6. Nominate your students and colleagues for travel grants, professional awards, and fellowship in the American Academy of Microbiology.

Over my 40-year career, clinical microbiology has been faced with unimaginable challenges on a global scale which impact all of humanity, whether it has been AIDS, the specter of untreatable microorganisms due to antimicrobial resistance, the reality of humans using microorganisms to intentionally harm others, and the emergence of numerous infectious agents whose detection has been facilitated by the development of amazing new technologies. Our understanding of the human microbiome certainly will challenge our notion of how we interact with microbes and how we define infectious diseases and will undoubtedly lead to novel new therapies which will improve and prolong life. As when I started on my own clinical microbiology journey almost 40 years ago, today is the most exciting time to be a clinical microbiologist. I wish you all the best on your journey.

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